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This annual report briefly describes progress on research in algorithms for optimal control problems. The principal research focus has been on a new approach to the parallel implementation of iterative algorithms for optimal control based on a two level parametrization of optimality conditions, and a secondary research focus has been the investigation of fault detection in the type of computational networks used for optimal control computations. Publications describing the results in detail are listed.

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FAULT TOLERANT PARALLEL IMPLEMENTATIONS OF ITERATIVE ALGORITHMS FOR OPTIMAL CONTROL PROBLEMS

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ABSTRACT

This annual report briefly describes progress on research in algorithms for optimal control problems. The principal research focus has been on a new approach to the parallel implementation of iterative algorithms for optimal control based on a two level parametrization of optimality conditions, and a secondary research focus has been the investigation of fault detection in the type of computational networks used for optimal control computations. Publications describing the results in detail are listed.

1. RESEARCH OBJECTIVES AND STATUS

The principal focus of our research is a new systematic approach to design optimal control algorithms that may be implemented on parallel machines. This approach is based on a two-level parametrization of first-order optimality conditions. The first level of parametrization is concerned with the decrease of the overall amount of operations, and the second level is concerned with parallelism. By introducing parametrization matrices in the first level and then factoring those matrices to exhibit the amount of parallelism desired in the second level as a function of the number of processing elements to be used, the resulting optimality conditions may be tailored to the computing network on which the computations are to be performed. The results have been published in the Journal of Parallel and Distributed Computing [1], and have been presented at the 1987 Annual International Conference on Parallel Processing [5], the 1987 Allerton Conference on Communication, Control and Computing [6], the Third SIAM Conference on Parallel Processing for Scientific Computing [7], and are also the subject of L. J. Podrazik's Ph. D. dissertation [8]. The research results concerning the convergence properties of relaxation algorithms that are used in parallel schemes have been published in Mathematical Programming [2].

The second research focus has been the investigation of fault detection in computational networks of the type analyzed in the course of our investigation of parallelism for optimal control. We have concentrated our effort in the study of system level fault models,and the results have been accepted for publication in the IEEE Transactions on Computers [4], and are also the subject of M. A. Kennedy's Ph. D. dissertation [3].

2. PH.D. COMPLETED: M.A. KENNEDY, MAY 1987

A STRUCTURAL APPROACH TO A SYSTEM LEVEL FAULT MODEL

ABSTRACT

The widespread use of computers, both large and small, has lead to an increase in the fault problem. This problem is most acute while the system is operating, because testing and fault diagnosis may not be possible during operation. One method of addressing this problem is to use the processing power of the system itself to enhance its ability to diagnose faults. System level fault models provide a framework for addressing this problem. These models represent a system in terms of its constituent processing elements, its faults, the tests to identify the faults, and the relationship between the faults and the test outcomes. This work considers the system level fault model of Preparata, Metze, and Chien which envisions a multiple computer system as a collection of processing elements and test links. The focus of the work is the relationship between the test link structure and the system diagnosis properties. Results include a test-link based method for partitioning the processing elements that provides both a new measure for comparing systems and an indication of the complexity of identifying the maximum diagnosability number of a system. This partitioning concept leads to new diagnosability conditions that fill in the gap between existing diagnosability conditions and their relationship to properties of the test link structure. The partition is also used to synthesize improved algorithms for identifying the maximum diagnosability number of a system. Turning to implied faulty set properties useful in diagnosis, results for both constrained and unconstrained system structures are presented. Finally, these properties are incorporated into diagnosis algorithms.

3. Ph.D. COMPLETED: L. J. PODRAZIK, DECEMBER 1987

PARALLEL IMPLEMENTATIONS OF GRADIENT BASED ITERATIVE ALGORITHMS FOR OPTIMAL CONTROL PROBLEMS

ABSTRACT

The primary objective of this research is to develop new parallel techniques for solving optimal control problems that occur in online real-time applications. In view of the availability of inexpensive yet powerful hardware, the use of parallel processing techniques is proposed to satisfy both the speed constraints imposed by a real-time setting as well as the reliability requirements of an online system. Unlike previous parallel approaches to the solution of optimal control problems, the goal is to obtain an efficient solution by structuring the control algorithms to exhibit parallelism which match the given machine architecture. In order to achieve the goal, this work reexamines optimal control problems from the perspective of their first-order optimality conditions so that the issues of parallelism and machine architecture may be considered in the forefront of the algorithm synthesis. Results include the development of an efficient parallel procedure for gradient evaluation. Embedded in the parallel gradient evaluation procedure is a new technique for solving first-order linear recurrence systems which is synthesized as a function of the number of available computers. The synthesis approach for parallel recurrence solvers is also new and uses matrix factorization techniques to organize the computations for the given parallel environment. The results for parallel gradient evaluation are then exploited to produce efficient parallel implementations of iterative gradient based techniques to solve the linear quadratic regulator optimal control problem with hard control bounds. Finally, a practical multi-computer architecture is presented to provide an integrated parallel environment for the solution of time critical optimal control problems.

4. PUBLICATIONS: JANUARY 1987 - DECEMBER 1987

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[7] G. G. L. Meyer and L. J. Podrazik, Parallel Iterative Algorithms to Solve the Discrete LQR Optimal Control Problem with Hard Control Bounds, *Third SIAM Conference on Parallel Processing for Scientific Computing,* Los

Angeles, California, December 1-4, 1987.

[8] L. J. Podrazik, Parallel Implementations of Gradient Based Iterative Algorithms for Optimal Control Problems, a dissertation submitted the Johns Hopkins University in conformity with the requirements for the degree of Doctor of Philosophy, December 1987.

5. PERSONNEL

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